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(21) Japanese Patent Application No.:	H08-72605	(71) Applicant	000004112 NIKON CORPORATION 2-3, Marunouchi 3-chome, Chiyoda-ku, Tokyo
(22) Date of Application:	March 27, 1996	(72) Inventor	Shinji MIZUTANI c/o NIKON CORPORATION 2-3, Marunouchi 3-chome, Chiyoda-ku, Tokyo
		(74) Representative	Yusuke HIRAKI, patent attorney (and one other)

(54) [TITLE OF THE INVENTION] PROJECTION EXPOSURE APPARATUS

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[CLAIMS]

[Claim 1] A projection exposure apparatus characterized by comprising:

a substrate stage which is movable in a two-dimensional direction in a state that a photosensitive substrate is placed on the substrate stage;

a laser interferometer for detecting a two-dimensional position of the substrate stage;

a reticle stage on which a reticle is placed;

an illumination system which causes a light from a light source to come into the reticle;

a projection optical system which forms an image of the reticle on the photosensitive substrate placed on the substrate stage;

a chamber which surrounds the exposure apparatus;

an infrared ray imaging means for imaging inside of the chamber; and

a temperature controlling means;

wherein a temperature distribution inside the chamber is determined from an output image of the infrared ray imaging means, and the temperature controlling means performs temperature control so that a temperature inside the chamber is substantially uniform.

[Claim 2] The projection exposure apparatus according to claim 1, characterized in that the temperature controlling means controls at least one of a temperature of atmosphere

circulating inside the chamber, a temperature of the reticle, a temperature of the projection optical system, a temperature of the photosensitive substrate placed on the substrate stage, and an optical path-air conditioning temperature of the laser interferometer.

[Claim 3] The projection exposure apparatus according to claim 1 or 2, characterized in that the temperature controlling means controls a temperature and flow rate of a gas blown from an air-conditioning blow port and a temperature and flow rate of a fluid flowing in a predetermined portion of which temperature is to be controlled.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD TO WHICH THE INVENTION BELONGS]

The present invention relates to a projection exposure apparatus which is used for producing semi-conductor integrated circuits, liquid crystal displays, etc.

[0002]

[PRIOR ART]

In the photolithography step for forming semi-conductor elements, liquid crystal display elements, thin-film magnetic heads, etc., a pattern, which is formed on a photo mask or reticle (hereinafter referred to as "reticle"), is transferred onto a photosensitive substrate such as a wafer, glass plate, etc. which is coated with a photosensitizer such as a photoresist.

[0003] As an apparatus for performing the projection exposure, a projection exposure apparatus of a so-called step-and-repeat system is used in many cases; the projection exposure apparatus of the step-and-repeat system exposes a predetermined area of a photosensitive substrate, held on a substrate stage, with a pattern formed on a reticle, and then causes the substrate table to be stepped by a predetermined distance to performs the exposure with the pattern of the reticle again in a repeated manner. Further, as an exposure apparatus of another kind different from the exposure apparatus of the step-and-repeat system, there is also known a projection exposure apparatus of slit-scan system which exposes a pattern

of a reticle onto a photosensitive substrate while synchronously and relatively scanning the reticle and the photosensitive substrate with respect to an illumination area having a rectangular or circular-arc shape.

[0004] The pattern is usually exposed onto the photosensitive substrate by repeatedly performing, for a plurality of times, exposing a pattern onto the photosensitive substrate while overlaying the pattern with another pattern which is different from the pattern and which has been already formed on the photosensitive substrate. In the recent years, patterns formed on photosensitive substrates have been steadily made fine and minute, and thus the demand for overlay accuracy of the pattern (pattern overlay accuracy) becomes increasingly stringent. One of the factors affecting the pattern overlay accuracy is the magnification error of a projection lens. The magnification of projection lens is adjusted when the apparatus is installed. However, the projection lens absorbs a part of the exposure energy during the exposure, and the temperature of the projection lens is increased. Therefore, in a case that exposure light (exposure light beam) is continuously irradiated to the projection lens for a long period of time or that exposure operation is continuously performed for a long period of time, there is a possibility that the projection lens might undergo any temperature change and the magnification of the projection lens might be changed to such an extent that the magnification change cannot be ignored. Regarding the reticle

also, in a case that the reticle absorbs the exposure light and the temperature thereof is increased, there is a possibility that the reticle might be deformed and might cause any shift (deviation) of the pattern.

[0005] Therefore, in order to perform the overlay exposure highly precisely, it is necessary to perform temperature control and maintain the temperature inside a chamber accommodating the projection exposure apparatus to be as constant as possible. For this purpose, there has been performed such a temperature control inside the chamber by arranging resistor temperature sensors at main portions inside the chamber, for example, at an air blow port of an air-conditioning device, in the vicinity of a stage interferometer which measures the two-dimensional position of a substrate stage, at a projection lens, or the like, and by using the temperature information outputted from these temperature sensors so as to control the temperature inside the chamber.

[0006]

[PROBLEM TO BE SOLVED BY THE INVENTION]

According to the conventional method using the temperature sensor, temperature information only about a small number of points (positions) inside the chamber can be obtained. If any attempt is made to obtain the temperature information about the chamber as a whole, then a large number of temperature sensors should be arranged inside the chamber while being

dispersed (distributed) in the chamber, which is not very feasible in view of the cost. Consequently, since it is not possible to know the temperature distribution in the entire chamber and thus not possible to make the temperature inside the chamber be uniform; and the presence of temperature gradient causes convention, which in turn generates fluctuation in the air.

[0007] The present invention has been made in view of the foregoing problem associated with the conventional technique, and an object of the present invention is to detect the temperature distribution inside the chamber without using a large number of temperature sensors, and to make the temperature inside the chamber be uniform.

[0008]

[MEANS FOR SOLVING THE PROBLEM]

In the present invention, the above-described object is achieved by using a two-dimensional imaging device such as an infrared ray camera, etc. to image the inside of the chamber, by processing obtained image so as to obtain a thermograph (temperature distribution diagram) inside the chamber, and by performing the temperature control such as air-conditioning control for respective parts or portions inside the chamber based on the obtained thermograph.

[0009] Namely, the projection exposure apparatus according to the present invention is characterized by comprising: a substrate stage which is movable in a

two-dimensional direction in a state that a photosensitive substrate is placed on the substrate stage; a laser interferometer for detecting a two-dimensional position of the substrate stage; a reticle stage on which a reticle is placed; an illumination system which causes a light from a light source to come into the reticle; a projection optical system which forms an image of the reticle on the photosensitive substrate placed on the substrate stage; a chamber which surrounds the exposure apparatus; an infrared ray imaging means for imaging inside of the chamber; and a temperature controlling means; wherein a temperature distribution inside the chamber is determined from an output image of the infrared ray imaging means, and the temperature controlling means performs temperature control so that the temperature inside the chamber is substantially uniform.

[0010] By arranging the infrared ray imaging means at a several locations inside the chamber, it is possible to instantly measure the temperature distribution in the inside of the entire chamber, and further possible to efficiently uniformize the temperature distribution. With respect to the temperature of a portion or part as a blind spot for the infrared ray imaging means, a conventional temperature sensor is arranged at such a portion or part, thereby using the infrared ray imaging means and the conventional temperature sensor in combination. By doing so, it is possible to know the temperature distribution inside the chamber with a small number

of temperature measuring means, and with increased accuracy.

[0011] The temperature controlling means controls at least one, preferably all, of a temperature of atmosphere circulating inside the chamber, a temperature of the reticle, a temperature of the projection optical system, a temperature of the photosensitive substrate placed on the substrate stage, and an optical path-air conditioning temperature of the laser interferometer by controlling a temperature and flow rate of an air blown from a partial air-conditioning device arranged at each of parts or portions of the chamber, or by controlling a temperature and flow rate of a fluid which is flowed in or though a part or portion, of apparatus or device, of which temperature is to be controlled.

[0012]

[EMBODIMENT OF THE INVENTION]

In the following, an embodiment of the present invention will be explained. Fig. 1 is a schematic view explaining the arrangement, inside a chamber, of a projection exposure apparatus according to the present invention. A body of a projection optical system (projection optical system-body) is constructed of a light source 10, an optical system 12, a reticle 14, a projection optical system 16, a wafer stage 19, etc. An exposure light (exposure light beam) emitted from the light source 10 is reflected by a reflecting mirror 11, is made to be a light flux having a uniform intensity distribution by the optical system 12 constructed of a fly's eye integrator, etc.;

the optical path of the light flux is bent by a reflecting mirror 13, and uniformly illuminates the reticle 14 held on the reticle stage 15. A pattern formed on the reticle 14 is imaged, via the projection optical system 16, on a wafer 17 which is suction-attracted and held by a wafer holder 18 on the wafer stage 19.

[0013] The wafer stage 19 has a well-known structure in which a pair of blocks, movable in mutually orthogonal directions in a plane perpendicular to an optical axis AX of the projection optical system 16, are overlaid with each other, and the wafer stage 19 is driven by a driving means 22. The position of the wafer stage 19 is detected by measuring, with a laser interferometer 21, a distance between a movable mirror 20 which is fixed on the wafer stage 19 and the laser interferometer 21, and the two-dimensional position of the wafer 17 is adjusted based on the measured value. The positioning (positional adjustment) of the reticle 14 and the wafer 17 is performed by using an alignment system 23, etc. A reticle transporting section 31 performs exchange of the reticle 14. Wafers are accommodated in a cassette 32, and a wafer transporting section 33 takes out the wafers one by one so that the wafers are placed on and exposed sequentially in the wafer stage 19.

[0014] The apparatus as a whole is arranged inside a chamber 40, and air circulating inside the chamber 40 is air-conditioned at a constant temperature by a main

air-conditioning device 51. In addition to this, heat-generating parts or portions of the apparatus or part or portions in the apparatus, for which highly precise temperature control is required, are each temperature-controlled individually by a method such as partial air-conditioning, liquid circulation, etc. Namely, the reticle 14 exposed to an illumination light (illumination light beam) is temperature-controlled by an air blown from a partial air-conditioning device 52; similarly, the projection optical system 16 which has a possibility that the temperature thereof might be increased by absorbing the exposure light is temperature-controlled at a constant temperature by temperature adjusting sections 53, 54 and 55 which circulate a liquid having a predetermined temperature. In this example, the projection optical system 16 is divided into three portions that are an upper portion 16a, an intermediate portion 16b and a lower portion 16c; and the projection optical system 16 is temperature-controlled highly precisely by assigning the temperature controls of the upper, intermediate and lower portions 16a, 16b and 16c to the first, second and third adjusting controlling sections 53, 54 and 55, respectively. Further, the optical path of the laser interferometer 21 which measures the position of the wafer stage 19 is temperature-controlled by an air blown from a partial air-conditioning device 56; and the wafer holder 18 which fixes the wafer 17 thereon is temperature-controlled by a fourth

temperature controlling section 57 which circulates a liquid having a predetermined temperature. The alignment system 23 is also temperature-controlled by a temperature adjusting section 58 which circulates a liquid having a predetermined temperature.

[0015] Note that the illumination system including the light source 10 which generates heat in a great amount is accommodated in another chamber 41 which is independent from the chamber 40, and the temperature control for the illumination system is performed by a different system, thereby preventing the heat generated in the illumination system from entering directly to the inside of the chamber 40.

[0016] Fig. 2 is a conceptual view of the partial air-conditioning device 56 which performs air-conditioning for the optical path of the laser interferometer. The partial air-conditioning device 56 is provided with a duct 90 which guides outside air (open air) or the air circulating inside the chamber 40, a heater 91 which heats the air flowing through the duct 90 and an open/close valve 92, and is configured to be capable of adjusting the temperature and flow rate of the air blown from the blow port of the partial air-conditioning device 56. The partial air-conditioning device 52 which performs partial air-conditioning for the reticle 14 also has a similar construction to that of the partial air-conditioning device 56, and is configured to blow an air, of which temperature and flow rate are adjusted, toward the reticle 14. The temperature

adjusting sections 53, 54, 55, 57 and 58 each of which performs temperature control by circulating the liquid are configured to be capable of adjusting, with a heater and a flow-rate controlling valve, the temperature and flow rate of the liquid which is being circulated. Note that it is also possible to provide a heat pump instead of the heater, and to realize cooling control in addition to the heating control.

[0017] A plurality of infrared ray imaging devices 61, 62, ... etc. are arranged inside the chamber 40 and perform imaging of (take images of) the respective devices or components arranged inside the chamber 40 all the time or at a predetermined time interval. The plurality of infrared ray imaging devices are preferably arranged so as to cover all the interior of the chamber 40. The images taken by the respective infrared ray imaging devices 61, 62, 63 are inputted to and processed by an image processing device 71 as shown in Fig. 3. In the image processing device 71, a distribution diagram of infrared emission intensity is prepared with a well-known method based on the images of the respective devices or components arranged in the chamber 40, and is converted to a temperature distribution diagram (thermograph). In a case that there are locations or portions, inside the chamber 40, which are blind spots for the infrared ray imaging devices 61, 62 and 63, resistor temperature sensors 66, 67 are arranged at such locations or portions; and it is possible to obtain temperature distribution data inside the entire chamber 40 by additionally

considering the data obtained from the resistor temperature sensors 66, 67 as well.

[0018] A main controller 72 determines the temperatures of the respective parts or components inside the chamber 40 from the data of thermograph obtained by the image processing device 71, and calculates temperature controlling parameters for the partial air-conditioning devices 52, 56, or temperature controlling parameters for the temperature adjusting sections 53, 54, 55, 57 and 58 by the liquid circulation, which are required to make the temperature distribution be uniform and to eliminate the temperature gradient. The calculation of the temperature controlling parameters can be performed by the PID calculation, and is finally converted to data of valve opening angle and data of current for heater (or heat pump) of the partial air-conditioning devices 52, 56, and converted to data of current for the temperature-adjusting heater (or heat pump) for adjusting the temperature of the liquid circulated by the temperature adjusting sections 53, 54, 55, 57 and 58 and to data of valve opening angle for the flow-rate controlling valve; and these data are supplied to control units 81 to 87, respectively.

[0019] Fig. 4 is a conceptual view of an example of thermograph obtained by processing the image, of the projection optical system 16 taken by the infrared ray imaging device 61, with the image processing device 71. The temperature is represented by the density of hatching, showing that a portion with a high density of the hatching has a high temperature. The

drawings shows that the upper portion of the projection optical system 16 has a higher temperature than the intermediate and lower portions thereof. In this case, although it depends as to how the temperature distribution is at another portion or location other than the projection optical system 16, an instruction would be generally issued by the main controller 72 with respect to a temperature adjusting unit 84 which controls the first temperature adjusting section 53 so as to circulate a liquid having a temperature lower than liquid(s) circulated by temperature adjusting units 85, 86 which control the second and third temperature adjusting sections 54, 55, respectively. It is allowable to display the thermograph, which is obtained by performing processing in the image processing device 71, as shown in Fig. 4 on a monitor such that an operator can observe the thermograph if necessary.

[0020] The main air-conditioning control unit 81 controls the current of the heater (or heat pump) and the opening angle of the open/close valve of the air conditioning device 51 in accordance with the instruction from the main controller 72. Similarly, the reticle partial air-conditioning control unit 82 and the laser interferometer-optical path air-conditioning control unit 83 control the currents of the heaters (or heat pumps) and the opening angles of the open/close valves of the partial air-conditioning device 52 which blows the air toward the reticle 14 and the partial air-conditioning device 56 which blows the air toward the optical path of the laser

interferometer 21, respectively, in accordance with the instructions from the main controller 72. Further, the wafer holder-temperature adjusting unit 87 controls the temperature adjusting section 57 in accordance with the instruction from the main controller 72, so as to control the temperature and flow rate of the liquid which is made to circulate in the wafer holder 18. By performing these series of procedures sequentially and performing the circulation control, the temperature distribution inside the chamber 40 is made to be uniform (is uniformized). By changing the focuses of the infrared ray imaging devices 61, 62 and 63, it is also possible to virtually obtain a three-dimensional temperature distribution, thereby making it possible to perform the air-conditioning control with increased precision. Further, the present invention is also applicable, for example, to heat-source search during the adjustment of the apparatus, etc. In such a case, it is possible to shorten the time required for the adjustment as compared with the conventional technique.

[0021]

[EFFECT OF THE INVENTION]

According to the present invention, it is possible to uniformize the temperature distribution inside the chamber, and also to reduce the influence of air fluctuation, etc., and to increase the exopsure accuracy.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1] Fig. 1 is a schematic view explaining the

arrangement inside a chamber of a projection exposure apparatus according to the present invention.

[FIG. 2] Fig. 2 is a conceptual view of a partial air-conditioning device which performs air-conditioning for the optical path of laser interferometer.

[FIG. 3] FIG. 3 is a schematic diagram of a control system.

[FIG. 4] FIG. 4 is a conceptual view of an example of thermograph obtained by imaging the projection optical system.

[EXPLANATION OF REFERENCE NUMERALS]

10 light source

11 reflecting mirror

12 optical system

13 reflecting mirror

14 reticle

15 reticle stage

16 projection optical system

17 wafer

18 wafer holder

19 wafer stage

20 movable mirror

21 laser interferometer

22 driving means

23 alignment microscope

31 reticle transporting section

32 cassette

33 wafer transporting section

40, 41 chamber

51 main air-conditioning device

52, 56 partial air-conditioning device

53, 54, 55, 57, 58 temperature adjusting section

61, 62, 63 infrared ray imaging device

66, 67 temperature sensor

71 image processing device

72 main controller

81 main air-conditioning control unit

82 reticle partial air-conditioning control unit

83 laser interferometer-optical path air-conditioning control unit

84, 85, 86 projection optical system-temperature adjusting unit

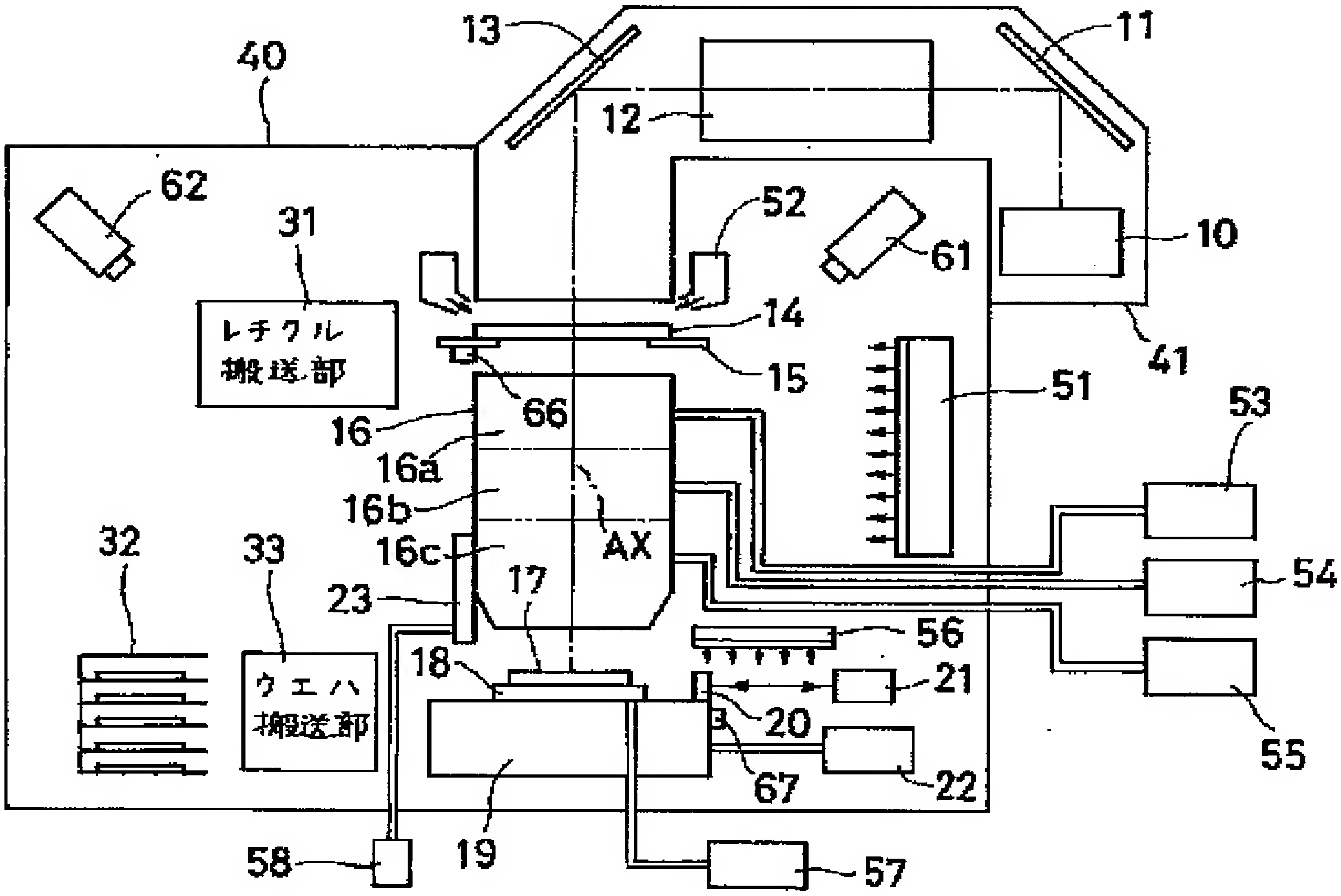
87 wafer holder-temperature adjusting unit

[ABSTRACT]

[PROBLEM TO BE SOLVED] To detect temperature distribution inside a chamber to uniformize the temperature inside the chamber.

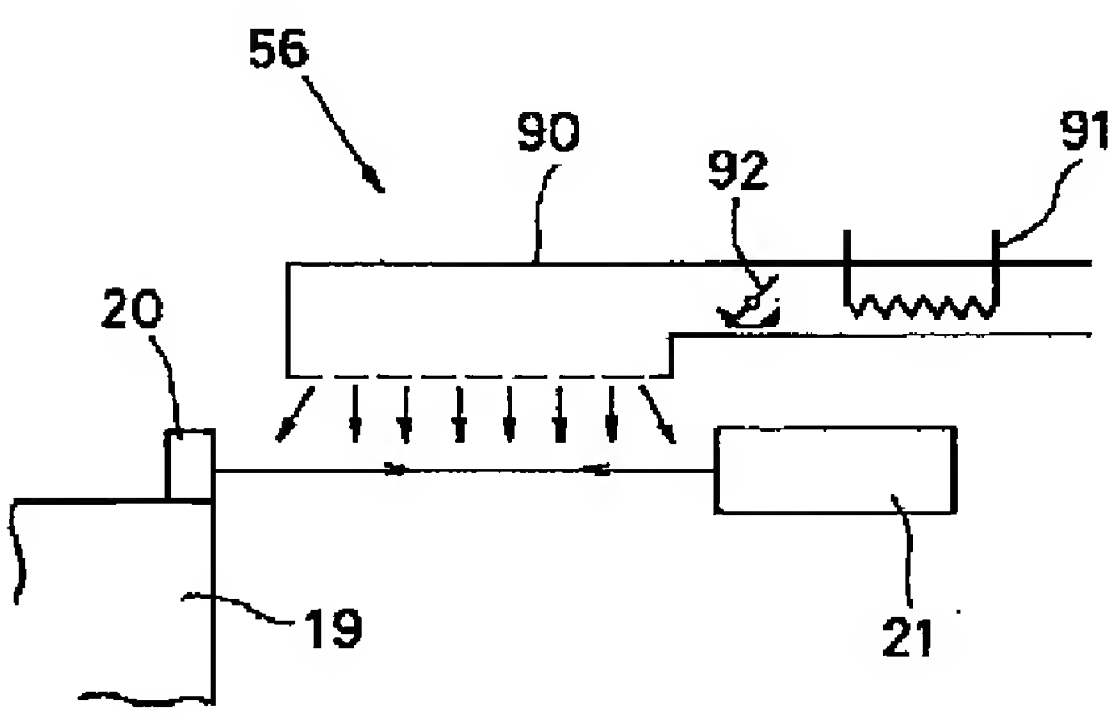
[MEANS FOR SOLUTION] Two-dimensional imaging devices 61, 62 such as infrared ray cameras are used to image the inside of a chamber 40 and obtained image is processed to thereby obtain a thermograph (temperature distribution diagram), inside the chamber, based on which the temperature and flow rate for performing partial air-conditioning of respective parts or portions inside the chamber, etc. are optimally controlled. The temperature control is performed by entirely controlling temperature of atmosphere circulating inside the chamber with an air-conditioning device 51, and by controlling temperatures of a reticle 14, a projection optical system 16 and a wafer 17 or controlling temperatures of respective parts or portions, such as a temperature of the optical path of a laser interferometer 21, with partial air-conditioning devices 52 and 56 and temperature adjusting sections 53, 54, 55 and 57 which circulate a liquid.

[FIG. 1]

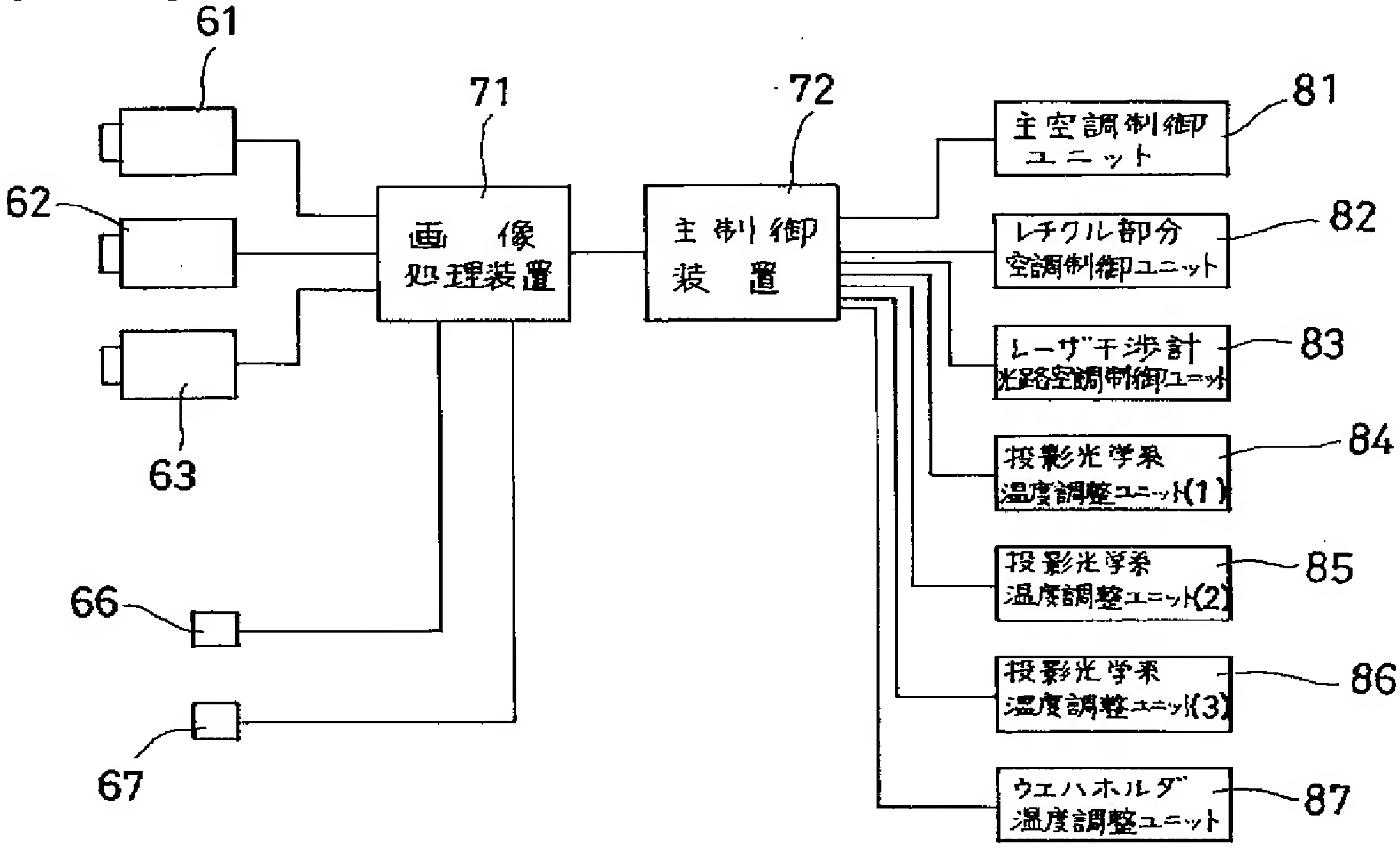


31 reticle transporting section
33 wafer transporting section

[FIG. 2]



[FIG. 3]



71 image processing device
72 main controller
81 main air-conditioning control unit
82 reticle partial air-conditioning control unit
83 laser interferometer-optical path air-conditioning control unit
84 projection optical system-temperature adjusting unit (1)
85 projection optical system-temperature adjusting unit (2)
86 projection optical system-temperature adjusting unit (3)
87 wafer holder-temperature adjusting unit

[FIG. 4]